

METHOD AND APPARATUS FOR HIGH FLY WRITE DETECTION USING
STORED AMPLITUDE VALUES

CROSS-REFERENCE TO RELATED APPLICATIONS

5 The present application is a continuation-in-part of U.S. Patent Application Serial
No. 09/649,660, filed August 29, 2000, entitled "HIGH FLY WRITE DETECTION
METHOD." Priority is claimed from U.S. Patent Application Serial No. 09/649,660 and
from U.S. Provisional Patent Application No. 60/217,978, filed July 13, 2000, entitled
10 "HIGH FLY WRITE DETECTION USING AMPLITUDE VALUES IN ERC", which are
incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates to the flying height of disk drive transducer heads
over the surface of magnetic storage disks. In particular, the present invention relates to
15 the detection of high fly write conditions in a computer disk drive.

BACKGROUND OF THE INVENTION

Computer disk drives store information on magnetic disks. Typically, the
information is stored on each disk in concentric tracks, divided into sectors. Information
is written to and read from a disk by a transducer head, mounted on an actuator arm
20 capable of moving the transducer head radially over the disk. Accordingly, the movement
of the actuator arm allows the transducer head to access different tracks. The disk is
rotated by a spindle motor at a high speed, allowing the transducer head to access
different sectors on the disk. The transducer head may include separate or integrated read
and write heads.

when the read head passes over an automatic gain control (AGC) field on the disk. In general, automatic gain control fields are written to computer disk drive storage disks during manufacturing. AGC fields are usually located in "servo sectors" or "hard sectors," which are areas extending radially across the disk that contain servo positioning information. In general, automatic gain control fields provide a reference magnetic field strength, so that the gain added to read signals by the hard disk drive's channel can be appropriately adjusted.

During the manufacture of a hard disk drive, servo sector information is written to the disk. During this "track writing" procedure, transducer heads having a write head that is about 2/3 the width of a data track are used. Because the AGC fields are the width of an entire data track, each AGC field must be written by at least three passes of the write head. This "stitching" together of the AGC fields causes the AGC fields to be vulnerable to manufacturing defects that result in AGC fields having unevenly spaced magnetic transitions. These unevenly spaced magnetic transitions can in turn result in magnetic fields of uneven strength. These manufacturing defects result in the production of signals in the read head that vary in amplitude. Although the varying magnetic strength of the AGC fields does not prevent them from functioning in connection with their primary gain control function, it does prevent high fly event detection systems dependent upon comparison with a standardized AGC field amplitude from operating with high sensitivity. In addition to defects within individual AGC fields, defects resulting in undesired variations in the magnetic strength of the AGC fields may arise between adjoining AGC fields, where the fields are aligned radially across all or a portion of the

disk. Because of these variations between different AGC fields, they cannot be used to detect a change in the flying height of a transducer head from one AGC field to another. This is because a change in the detected amplitude from one AGC field to another could be caused by the above-mentioned manufacturing defects and variations, as well as by a
5 change in the flying height of the transducer head.

Another method of detecting a high fly write event is disclosed by U.S. Patent No. 5,909,330 to Carlson et al., assigned to the assignee of the present invention. According to Carlson, whether the flying height of a read/write head above a disk is within an acceptable range can be determined by the resolution of a signal read by the read head. In
10 particular, this method relies upon the decrease in the number of detected signal peaks as the flying height of the read head increases.

Another method of detecting a high fly write event is disclosed by U.S. Patent Application Serial No. 09/649,660 to Liikanen et al., assigned to the assignee of the present invention, and of which the present application is a continuation in part.
15 According to Liikanen, the average amplitude of the signal derived from a plurality of servo sector position bursts or group of bursts is determined, and is compared to the observed amplitude of a one of the servo sector position bursts or group of bursts. If the comparison indicates that the strength of the observed signal is less than the average amplitude by at least a predetermined amount, a write fault error may be triggered. This
20 method avoids the problems associated with monitoring a signal derived from the AGC fields. In particular, the servo sector position bursts provide a signal having a more consistent amplitude.

Sensitivity is important in detecting high fly write events, because such events are transient in nature. For example, a high fly write event may occur when a transducer head passes over a particle on the surface of the disk. The particle may cause a perturbation in the boundary layer of air supporting the transducer head, causing the head to fly at greater than a desired distance from the disk surface. In a typical high fly event, the transducer head flies at too great a height for one or two sectors of the disk.

Therefore, it can be appreciated that detection of a high fly write event preferably is made on the basis of information collected over a single sector of the disk. Furthermore, because the change in height is small, and because the high fly write event may last for extremely short periods of time, it is important that the high fly write detection mechanism be extremely sensitive, so that high fly write events can be detected even at the beginning or end of such an event.

In addition, when a running average value is used as a reference, this method requires charging the algorithm used to develop the average value. Accordingly, such methods may not be suitable for use immediately following a head switch, because they are not able to immediately provide a reference value.

For the above stated reasons, it would be advantageous to provide a method and apparatus for quickly and reliably sensing a high fly write event in a computer disk drive. In addition, it would be advantageous to provide a method and an apparatus for detecting high fly write events that did not adversely affect the performance of the disk drive. Furthermore, it would be advantageous to provide a method and apparatus that can be implemented at an acceptable cost and that are reliable in operation.

SUMMARY OF THE INVENTION

In accordance with the present invention, a method and an apparatus for detecting the flying height of a disk drive transducer head over the surface of a magnetic storage disk are provided. According to the present invention, the strength or amplitude of a signal derived from data written to the magnetic disk is compared to a standard or reference amplitude established for that piece of data to determine whether the transducer head is in a high flying condition. The present invention allows high fly events to be detected even where the transducer head is in a high flying condition for only a very brief period of time.

According to an embodiment of the present invention, the average amplitude of a signal derived from a particular piece of data stored on the disk is determined. This average amplitude is then stored on the disk for use as a standard or reference amplitude. During a write operation, the observed amplitude of the signal derived from the particular piece of data is compared to the stored standard value for that piece of data. If the result of the comparison is unfavorable, a high fly write condition is indicated. Standard or reference amplitudes are established for a plurality of pieces of data. For example, reference amplitudes may be established for a piece of data in or associated with each hard sector or for each data sector on a disk.

In accordance with a further embodiment of the present invention, a marginal value is added to the average amplitudes stored to the disk prior to comparing the resulting standard value to the observed value in order to allow for acceptable variations in flying height due to changes in environmental conditions and drive tolerances.

Alternatively, the values stored on the disk may be modified by adding a marginal value before storing the resulting standard values on the disk. In accordance with still another embodiment of the present invention, an undesirable flying height may be indicated if an observed amplitude is outside of a range of amplitudes established on one or both sides of the corresponding stored reference amplitude.

In accordance with an embodiment of the present invention, the data that is read from the magnetic disk to establish reference amplitudes, and that is observed during write operations, is automatic gain control (AGC) data. In accordance with still another embodiment of the present invention, the data that is read in calculating reference amplitudes and that is observed during write operations is servo sector position burst data. In general, any piece of data that can be relied on to exist after the disk drive has been delivered to an end user or after a calibration procedure can be used in connection with the present invention.

In accordance with still another embodiment of the present invention, the reference amplitudes are stored on the disk as part of servo sector data. The servo sector data may be located in a hard sector of the disk, or may be stored in a servo in data sector.

In accordance with one embodiment of the present invention, reference amplitudes are determined and stored on the disk prior to releasing the disk drive to an end user. In accordance with still another embodiment of the present invention, the reference amplitudes may be determined, or re-determined, after delivery of the disk drive to an end user, and those values may then be stored on the disk.

In accordance with an embodiment of the present invention, an average amplitude for use as a reference amplitude is determined and stored on the disk for each AGC field on the disk. Alternatively, average amplitudes may be calculated and stored for less than all of the AGC fields on the disk. As a further alternative, a reference amplitude is
5 determined for a group of servo sector position bursts on the disk.

Based on the foregoing summary, a number of salient features of the present invention are readily discerned. A computer disk drive having the capability of detecting a high flying condition, including high fly write events, and thereby helping to ensure the integrity of data written to a disk, is provided. In particular, a method and an apparatus
10 for detecting high fly write events with great sensitivity are provided. Furthermore, the method and the apparatus of the present invention are operable immediately, including following a head switch.

Additional advantages of the present invention will become readily apparent from the following discussion, particularly when taken together with the accompanying
15 drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram depicting a disk drive system that can utilize features of the present invention;

Fig. 2 is a representation of a sectional view of a disk and an associated transducer head illustrating the flying height of the transducer head above the disk surface;
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Fig. 3 is a schematic illustration of an arrangement of information on a magnetic storage disk according to one embodiment of the present invention;

Fig. 4 is a flow chart depicting the development of reference amplitude values in accordance with an embodiment of the present invention; and

Fig. 5 is a flow chart depicting the operation of a system in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

With reference now to **Fig. 1**, the major components of a hard disk drive, generally identified as hard disk drive **100**, are illustrated. As shown in **Fig. 1**, a hard disk drive generally includes a magnetic storage disk **104** rotatably mounted to a base **108** by a spindle bearing **112**. Within the spindle bearing **112** is a spindle motor (not shown) for rotating the disk **104** relative to the base **108**. An actuator arm **114** has at a first end a transducer head **116**. The actuator arm **114** is pivotally interconnected to the base **108** by an actuator arm bearing **118**. At a second end, the actuator arm **114** is interconnected to a voice coil motor **120** capable of pivoting the actuator arm **114** about the bearing **118**.

The operation of the voice coil motor **120** is controlled by a servo control unit **124**, which provides appropriate control signals to the voice coil motor **120**. In general, the voice coil motor **120** positions the transducer head **116** over a desired track **106** on the storage disk **104**.

A controller **128** provides information to the servo control unit **124** regarding the desired or target track **106**. The controller **128** additionally provides timing information to the channel **132**. The channel **132** is operative for processing data flowing between a host computer **136** and the disk **104**. The interface **140** is operative for managing the

flow of data between the host unit **136** and the disk drive **100**, and receives commands from the host **136** for delivery to the controller **128**.

The tracks **106** are divided into a plurality of data sectors **144a-d** and a plurality of servo sectors **148a-d**. A plurality of zones **152a-b** may be formed from groupings of tracks **106**. As shown in **Fig. 1**, the servo sectors **148** may extend radially across the disk **104** in the form of wedges or spokes. However, it should be appreciated that the servo sectors may be more numerous toward the outer circumference of the disk **104**, and less numerous toward the inner circumference of the disk, for instance, where zone density recording techniques are used to increase the storage capacity of the disk **104**.

As an example of the operation of the disk drive **100**, in response to a digital signal from the host computer **136** to write data to the disk **104**, the channel **132** processes the signal from the host computer **136** and converts it to a variable write current signal that is delivered to the transducer head **116**. The actuator arm **114** carries the transducer head **116** and positions the head **116** above the target track **106**. In particular, the voice coil motor **120** moves the actuator arm **114** to position the transducer head **116** above the target track **106**. The voice coil motor **120** is responsive to a servo control signal from the servo control unit **124**.

During a read operation, the controller **128** receives (via the interface **140**) a request from the host **136** for a particular piece of information stored on the disk **104**.

The controller **128** issues a control signal to the servo control unit **124**, which in turn actuates the voice coil motor **120** to position the transducer head **116** over the target track **106**. After the transducer head **116** is in position, data from the track **106** is read by the

transducer head **116**, and the resulting signal passed to the channel **132**. Channel **132** receives the analog read signal provided by the transducer head **116**, and converts that signal into a digital signal that can be understood by the host **136**.

With reference now to **Fig. 2**, a representation of a sectional view of a storage disk **104** and transducer head **116** is illustrated. As shown in **Fig. 2**, during operation, the head **116** (which, as illustrated, includes a slider) is raised above the surface of the disk **104** by a spacing **200** known as the flying height of the head **116**. The spacing or flying height **200** is created by the interaction between air currents above the surface of the disk **104** caused by the rotation of the disk **104** and the aerodynamic qualities of the slider of the transducer head **116**.

With reference now to **Fig. 3**, the informational content of a portion of a disk **104** surface in a typical disk drive **100** is illustrated. As illustrated in **Fig. 3**, the disk **104** includes data sectors **144a** and **144b** separated by a servo sector **148a** containing positioning information. In a typical disk drive, a plurality of servo sectors **148** extend radially across the surface of the disk **104** to divide it into a plurality of data regions. As will be appreciated by one skilled in the art, more than one data sector **144** may be positioned between two servo sectors **148**. Therefore, the number of data sectors **144** on a disk **104** is often greater than the number of servo sectors **148**. The data sectors **144a** and **144b** are, for illustration purposes, shown with three tracks **106a**, **106b** and **106c** in the first data sector **144a**, and three data tracks **106d**, **106e** and **106f** in the second data sector **144b**. However, it will be appreciated that, in a typical disk drive, there may be

thousands of data tracks **106** concentrically arrayed across the disk **104**, each divided into well over one-hundred sectors.

With continued reference to **Fig. 3**, the servo sector **148a** is shown to include a plurality of automatic gain control (AGC) fields **300**. The AGC fields **300** extend across the disk **104** radially, from an inside diameter to an outside diameter of the disk **104**. In **Fig. 3**, the AGC fields **300** are shown to extend across the disk **104** in continuous lines, although this need not be the case. Generally, each AGC field **300** contains a signal of a calibrated strength. As the transducer head **116** passes over the AGC field **300**, the strength of the signal passed through the channel **132** is monitored. This signal strength is used to adjust the gain imparted to signals read by the transducer head **116**. Generally, at least after an initial adjustment to the gain of the channel **132** has been made, adjustments to the amount of gain are made gradually. In part, this is because the amplitude of a single AGC field **300** cannot be precisely controlled. In addition, allowing rapid changes to the amount of gain in the channel **132** would interfere with the accurate detection of high fly events according to the present invention. Therefore, it is preferable to prevent rapid changes to the gain imparted to read signals by the channel **132** after an initial amount of gain has been set.

Also illustrated in **Fig. 3** is a servo sector position information region **304** having servo sector position bursts A **308**, B **312**, C **316** and D **320**. In a typical disk drive **100**, the servo sector position bursts **308-320** are used to enable the transducer head **116** to be precisely positioned over the center of a target data track **106**. The servo sector position bursts **308-320** may, in addition to the configuration illustrated in **Fig. 3**, be arranged in

alternative patterns. In addition, a lesser or greater number of servo sector position bursts 308-320 may be provided in connection with a particular sector 148 of a particular track 106. For example, only A 308 and B 312 servo sector position bursts may be provided.

Although the AGC fields 300 are shown in Fig. 3 as belonging to the servo sector 148, this is not required. For example, the AGC fields 300 may be written to some or all of the data sectors 144 as part of a servo-in-data sector by the transducer head 116 of the disk drive 100. In general, a servo-in-data sector may contain any data for which the information content is not critically dependent on the physical location of the data on the disk. For example, an AGC field 300 can be located at some distance from the data for which the gain in the channel 132 is set using that AGC field. In contrast, a servo sector position burst 308, 312, 316 or 320 is used to determine the position of the transducer head 116 relative to the track 106 being followed, and therefore the information it provides is critically dependent on the physical location of servo sector position burst 308, 312, 316 or 320. Writing the AGC fields 300 to data sectors 144 as part of servo-in-data sectors reduces the amount of time that is required by a servo track writer to prepare a disk 104 for inclusion in a disk drive 100, because servo-in-data may be written by the transducer head 116. In addition, servo data, including AGC fields, written to data sectors as part of servo in data fields can be re-written after delivery of the drive to an end user if recalibration of the drive is required. Other servo data that can be stored in a servo in data field includes embedded runout correction (ERC) values, and reference amplitudes for use in connection with the detection of high flying conditions, as will be explained in greater detail below.

Although data stored in servo-in-data sectors can generally be understood to be data providing information that is not critically dependent on the physical location of the data, it should be noted that any data, such as an AGC field, used in connection with determining the flying height **200** of a transducer head **116** should be located adjacent or in close proximity to the data sector for which the flying height **200** is being assessed. For a complete explanation of servo-in-data sectors, see U.S. Patent Application Serial No. 09/454,125, filed December 3, 1999, the entire disclosure of which is incorporated by reference herein in its entirety.

According to the present invention, the amplitude of a signal derived from data, such as an AGC field, associated with one or more data sectors **144** is monitored in the channel **132**. Because the amplitude of a signal derived from data written to a disk **104** varies with the flying height **200** of the transducer head **116**, the amplitude of the detected signal is indicative of the flying height **200** of the transducer head **116**. Therefore, generally stated, the present invention compares the amplitude of a signal derived from a particular piece of data to a standard amplitude established for that piece of data.

Accordingly, the data used to monitor the flying height **200** of the transducer head **116** must not be altered during normal operation of the disk drive **100**. That is, the data used in connection with monitoring the flying height **200** of the transducer head **116** should be servo data, whether that data is stored in a servo sector **148**, or is part of a servo in data sector stored in a data sector **144** portion of the disk **104**. It should be appreciated that, as used herein, servo data refers to data that is not altered during normal operation of the disk drive **100**, whether or not such data is written to the disk **104** by a servo track writer,

or by the transducer head **116** of the disk drive **100** during calibration of the disk drive **100**. Accordingly, data that may be used in connection with monitoring the flying height **200** of a transducer head **116** over a disk **104** includes AGC fields **300**, servo sector position bursts **308-320**, or ERC values.

5 With reference now to **Fig. 4**, a flow chart illustrating the development of reference amplitude values in accordance with one embodiment of the present invention is shown. Initially, at step **400**, diagnostic procedures are initiated. In addition to the determination of reference amplitudes as described below, the diagnostic procedures may include flaw scan detection and the determination of embedded runout correction values. As can be appreciated, the diagnostic procedures are performed after assembly of the disk drive **100**. Accordingly, the determination of reference amplitudes can be accomplished during post assembly procedures, and without requiring the use of a servo track writer.

10 At step **404**, the amplitude of an automatic gain control field **300** is determined. Each time the amplitude of an AGC field **300** is measured, that value is added to any previously measured amplitude or amplitudes for that field so that a sum is calculated (step **408**). Accordingly, if a measured amplitude for a particular automatic gain control field **300** is the first measurement with respect to that AGC field **300**, the sum is simply the measured amplitude.

15 At step **412**, a determination is made as to whether additional measurements of the automatic gain control field **300** amplitude are desired. The number of measurements that are taken may be set in the firmware of the disk drive **100** or may be selected by a user. If additional measurements are indicated, the system returns to step **404** to take an

additional measurement. At step **408**, the additional measurement is added to any previous measurements of the amplitude of the signal derived from that AGC field **300**.

If it is determined at step **412** that no additional measurements of the amplitude of the AGC field **300** are indicated, the system proceeds to calculate an average amplitude for the automatic gain control field **300** (step **416**). As can be appreciated by one of skill in the art, the greater the number of individual measurements of an AGC field's amplitude used to construct an average, the more the effects of noise and other random influences on the measured amplitude are suppressed. At step **420**, the average amplitude for the automatic gain control field is written to the disk as a high fly write value for the data sector **144** associated with the AGC field **300**. For example, the high fly write value is written to a servo in data sector containing other data associated with that data sector **144**, such as embedded runout correction data.

As can be appreciated, the above-described embodiment of the present invention can be implemented such that high fly write values may be calculated for a plurality of data sectors in parallel. For instance, the amplitude of signals derived from all of the AGC fields **300** in a track **106** on a disk **104** may be collected in series as the transducer head **116** traverses over the AGC fields **300**. From multiple passes over the AGC fields **300**, an average amplitude for each of the AGC fields **300** may be calculated.

Fig. 5 is a flow chart depicting the operation of a system in accordance with an embodiment of the present invention. In particular, **Fig. 5** illustrates the detection of a high fly write condition after a high fly write value for data associated with all or a plurality of the data sectors **144** on a disk **104** have been determined, such as described

above in connection with **Fig. 4**. Initially, at step **500**, a write command is received, for example from the host computer **136**. At step **504**, the amplitude of a signal derived from the AGC field **300** associated with the data sector **144** to which the data will be written is measured.

At step **508**, the high fly write value determined for the AGC field **300** is read from the disk **104**. At step **510**, a marginal value is added to the high fly write value to obtain a reference signal amplitude. In general, the marginal value is set to allow for variations in the amplitude of the signal from the AGC field **300** that are not severe enough to signal the occurrence of a high fly write condition. For example, noise in the channel **132** may cause some variance in the amplitude of the signal that is not indicative of a high fly write condition. In addition, where, for example, the disk drive **100** is calibrated in an environment having a higher pressure and/or a lower temperature than the environment in which the write operation is to be performed, the signal amplitude can be expected to be lower than the high fly write number. Therefore, the marginal value should be large enough to allow for variations in signal amplitude due to operation of the disk drive **100** at a range of pressures and temperatures that are within the normal operating parameters of the disk drive **100**. For purposes of illustration, the high fly write value may be 100 mV, the marginal value may be 20 mV, and the measured value may be 130 mV.

At step **512**, the measured amplitude is subtracted from the reference amplitude to obtain a difference. Next, a determination is made as to whether that difference is positive (step **516**). If the difference is positive, a high flying condition is signaled (step

520). In response to a high flying condition signal, the disk drive **100** may take various measures. For example, a second attempt to repeat the write operation may be made. If a high flying condition is again signaled during the additional attempt, the transducer head **116** may be vibrated or burnished in an attempt to remove any particles from the transducer head **116** that may be causing the high flying condition to occur.

If the difference is negative, the write operation is continued (step **524**). In other words, a high fly write condition does not exist. With respect to the example values noted above, the difference is negative (*i.e.* is not positive), indicating a flying height that is not excessive.

As can be appreciated, the above-described embodiment of the present invention stores a reference or high fly write value corresponding to all or a selected plurality of AGC fields **300** present on the disk **104**. During write operations, the amplitude of a signal derived from an AGC field **300** associated with one or more of the data sectors **144** to which the data will be written is monitored. The amplitude of the AGC field **300** is compared to a high fly write value that has been previously calculated for that particular AGC field **300**. As described above, a marginal value may be added to the high fly write value to allow for slight variations in the flying height **200**, such as may occur during normal operation of the disk drive **100**. Because a separate high fly write value is determined and stored for each AGC field that will be monitored, the present invention is able to function even if the amplitudes of those AGC fields **300** differ from one another due to manufacturing variations or defects. Additionally, because the measured amplitude for an AGC field **300** is not compared to an average derived from a plurality of

AGC fields, allowed variations from the high fly write number established for a particular AGC field **300** may be relatively small, without impeding the performance of the disk drive **100** by requiring numerous rewrite attempts and procedures designed to remove particles from the transducer head **116**.

5 Although the embodiment described in the examples above discusses the use of AGC fields **300** in connection with detection of a high flying condition, any data that is not altered during the normal operation of the disk drive **100** may be used. For example, the amplitude of ERC values or the amplitude of a signal derived from servo sector position bursts in sector preambles may be used. Of course, the high fly write value
10 should be derived from the same data (*e.g.*, the servo sector position bursts) that is later monitored in connection with the detection of high fly write events.

 According to still another embodiment of the present invention, a marginal value is added to the high fly write number before that number is stored on the disk **104**.

 According to still another embodiment of the present invention, the marginal value added
15 to the high fly write number may be varied according to the environmental conditions in which the disk drive **100** is operated, or according to a desired sensitivity to high fly write events.

 According to the present invention, a method and an apparatus for detecting high flying conditions in a computer disk drive are provided. In particular, the present
20 invention discloses a method and an apparatus for detecting high fly write events with great sensitivity, effectively protecting against data loss that may occur in connection with high flying conditions, including high fly write events, but without unduly limiting the

data throughput performance of the disk drive. According to the present invention, the amplitude of a signal derived from data written to a disk **104** is compared to a reference or high fly write number derived from that data. Where the observed signal strength or amplitude is less than the amplitude indicated by the high fly write number by at least a predetermined amount, a high flying condition is indicated. In response to the indication of the high fly condition, the disk drive may prohibit subsequent write operations for a period of time.

In the embodiment discussed in connection with **Fig. 5**, the amplitude of a piece of data is measured before that amplitude is compared to the reference amplitude for that piece of data. It will be appreciated by one of skill in the art that these steps may be reversed, such that the reference amplitude is read prior to measuring the amplitude. Such an embodiment may allow the monitored piece of data to be located in close proximity to the data sector with respect to which the write operation is to occur.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments described hereinabove are further intended to explain the best mode presently known of practicing the invention and to enable others skilled in the art to utilize the invention in such or in other embodiments and with various modifications required by their particular application or use of the

invention. It is intended that the appended claims be construed to include the alternative embodiments to the extent permitted by the prior art.